

# AIR CRUISERS

AEROSAFETY & TECHNOLOGY  
Emergency Evacuation Systems


**ZODIAC  
AEROSPACE**




## ENGINEERING DOCUMENT NUMBER 4208

### EXECUTIVE SUMMARY – EVACUATION SYSTEM ANALYSIS FROM CRASH OF ASIANA FLIGHT 214


(See Page 2 for Revision Control Sheet)

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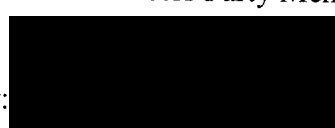
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## Revision Control Sheet

REV.	DATE	DESCRIPTION	APPROVAL
A	17 March 2014	Initial Issue	Robert Hentges

**1.0 PURPOSE**

The purpose of this document is to provide a summary of the analysis of the evacuation systems that were involved in the crash of Asiana Flight 214. This report considers facts gathered on-scene, during teardown, as well as subsequent post-crash testing.

**2.0 Abstract**

On July 6, 2013, a Boeing 777-200ER operated by Asiana Airlines as Flight 214 crashed in San Francisco, California. The aircraft experienced multiple, severe impacts during the crash sequence. Data recorders on the aircraft were not able to record those impact force levels because the recorders are located in the tail of the aircraft which was separated at the beginning of the crash sequence. Physical evidence such as bent seat posts and armrests as well as statements from passengers and crew indicate that among the impacts there were very high forces in the down direction and the right-to-left direction. Of the eight evacuation systems, two were utilized successfully to evacuate passengers and crew (Doors 1 & 2 left hand). Neither of the Door 4 slides were usable as the aft end of the fuselage suffered severe structural damage. Door 3 on the left side was not opened during the evacuation, therefore that slide/raft played no role. The door 3 slide/raft on the right side was prevented from being useable due to extensive debris piled outside of the door opening. The slide/rafts at doors 1 & 2 on the right side deployed inside the cabin during the crash sequence due to failure of the release mechanisms under the extreme crash forces. All slide/raft packboards on the right side of the aircraft suffered from torn or damaged release shafts in the pack release mechanism. None of the slides on the left hand side showed this release shaft tearing. Follow-on testing was conducted with NTSB support and cooperation to understand the level of force required to cause the release mechanisms to fail with the same failure mode of release shaft tearing. Test results show that the level of force was in excess of 12.4g's which exceeds the test requirements specified in FAR 25.561 (b) of 3g side and 6g down.

**3.0 REFERENCE DOCUMENTS FROM DOCKET SA-537**

Survival Factors 6 – Exhibit A – Survival Factors Group Chariman's Factual Report  
Survival Factors 6 – Exhibit B – Photographs  
Survival Factors 6 – Exhibit H – Tensile Test Plan and Results  
Survival Factors 6 – Addendum 1 – Attachment 1 – MGA Slide/Raft Testing Report

## 4.0 DOOR-BY-DOOR SUMMARY

Figure 1 shows a door-by-door high level summary of the evacuation systems performance from the crash of Asiana Flight 214.

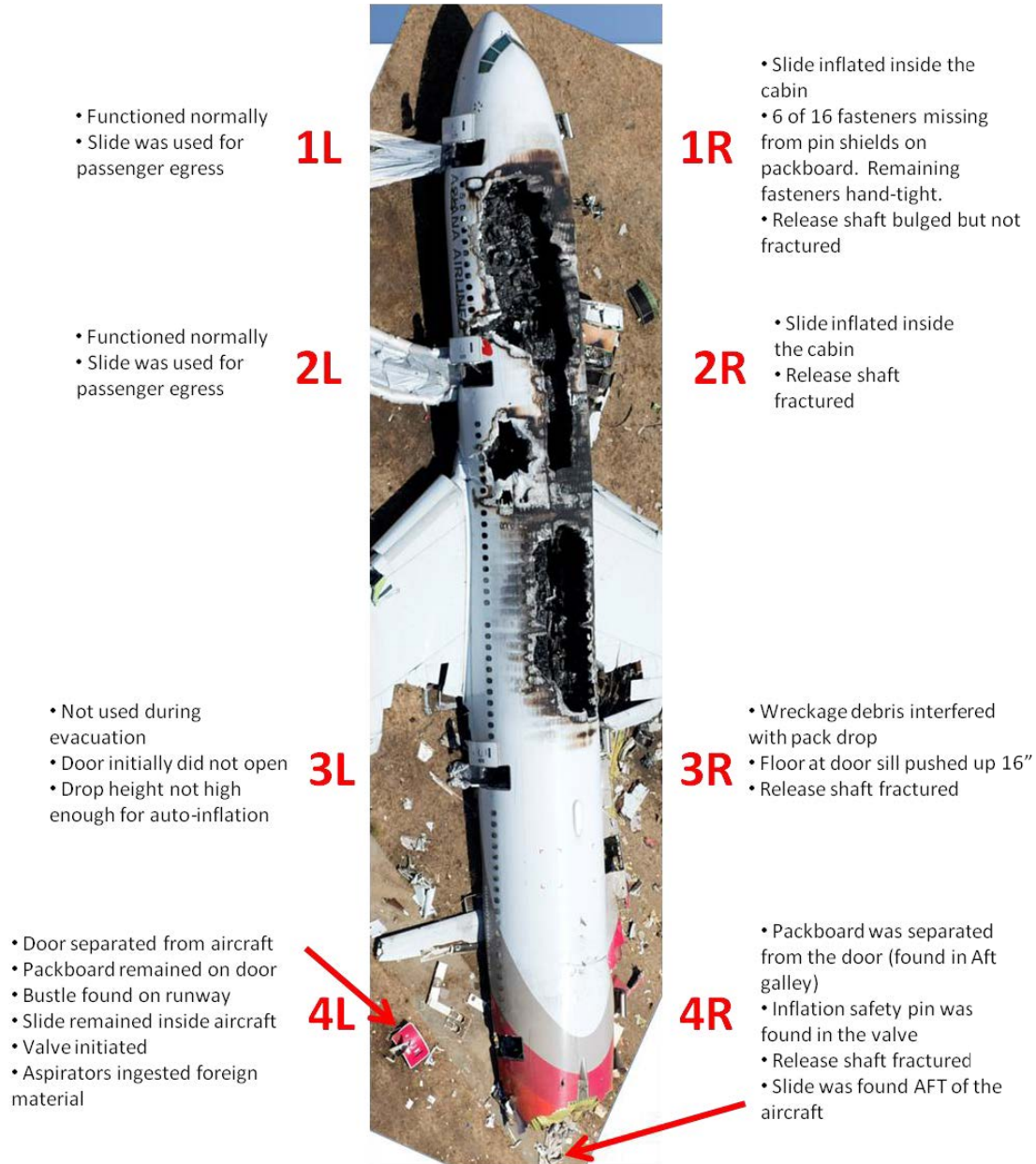


Figure 1. Door-By-Door summary



### 4.1 Door 1 Left Hand

Slide/raft functioned normally and was used by the crew and passengers to evacuate the aircraft. See Figure 2. The slide/raft was also used by first responders to enter the aircraft.

### 4.2 Door 2 Left Hand

Slide/raft functioned normally and was used by the crew and passengers to evacuate the aircraft. See Figure 2. The slide/raft was also used by first responders to enter the aircraft.



**Figure 2. Door 1 and Door 2 Left Hand**



## 4.3 Door 3 Left Hand

This door was not opened during the evacuation sequence. A flight attendant attempted to open the door but was not able to rotate the handle all the way. At some point in time after the evacuation was complete, the door was opened. It is not known who opened the door or at what time after the evacuation it was opened. The slide/raft did not automatically inflate following the door opening because the reservoir did not fall far enough to tension the inflation cable. The sill height was measured on-scene as 53 inches. The minimum sill height condition tested for qualification of this slide/raft with automatic inflation at this door location was 97 inches. Figure 3 shows that there is slack in the inflation cable at the top of the girt, which indicates that the cable was not tensioned as would be required to activate the valve. If the door had been opened during the evacuation by a flight attendant, he/she would have pulled the manual inflation handle as they are trained to do, likely resulting in a successful deployment and useable slide/raft.



**Figure 3. Door 3 Left Hand Inflation Cable Slack**



### 4.4 Door 4 Left Hand

The aircraft door at this location was separated from the aircraft during the crash sequence as shown in Figure 1 and was found thirteen feet away from the door sill. The packboard for the slide/raft remained on the door. The slide/raft was pulled partially aft inside the cabin. The inflation valve was actuated, however each aspirator ingested foreign material, preventing the slide from inflating. The floor below the door sill was missing and the slide/raft was sitting on the ground. See Figure 4.



**Figure 4. Door 4 Left Hand Inside Aft Cabin**



### 4.5 Door 4 Right Hand

The slide/raft was found on the ground, aft of the aircraft's pressure bulkhead, having been torn away during the crash sequence. See Figure 5. The packboard was found in the AFT galley.



**Figure 5. Door 4 Right Hand Sitting Aft of the Pressure Bulkhead**



### 4.5 Door 3 Right Hand

The aircraft floor at the door sill was pushed up by approximately 17 inches during the crash sequence. The door was opened during the evacuation. The slide/raft was not able to drop clear of the door below the door sill due to aircraft wreckage underneath the fuselage. This prevented the slide/raft from being useable. See Figure 6.



Figure 6. Door 3 Right Hand Sitting on Debris



### 4.6 Door 2 Right Hand

The slide/raft at the door 2 location on the right side inflated inside the cabin during the crash sequence. See Figure 7. The release of the pack from the packboard occurred due to excessive crash loads, resulting in fracturing of the release shaft. See Paragraph 5.0 for further discussion.



**Figure 7. Door 2 Right Hand**



### 4.7 Door 1 Right Hand

The slide/raft at the door 1 location on the right side inflated inside the cabin during the crash sequence. See Figure 8. The release of the pack from the packboard occurred due to excessive crash loads, resulting in release of the retention cables from the release shaft. Upon teardown, it was discovered that some of the pin shield fasteners on the release mechanism were loose and/or missing, thus the retention cable ball ends were able to release from the mechanism without tearing the release shaft. See Paragraph 7.1 for further discussion of the pin shield fasteners.

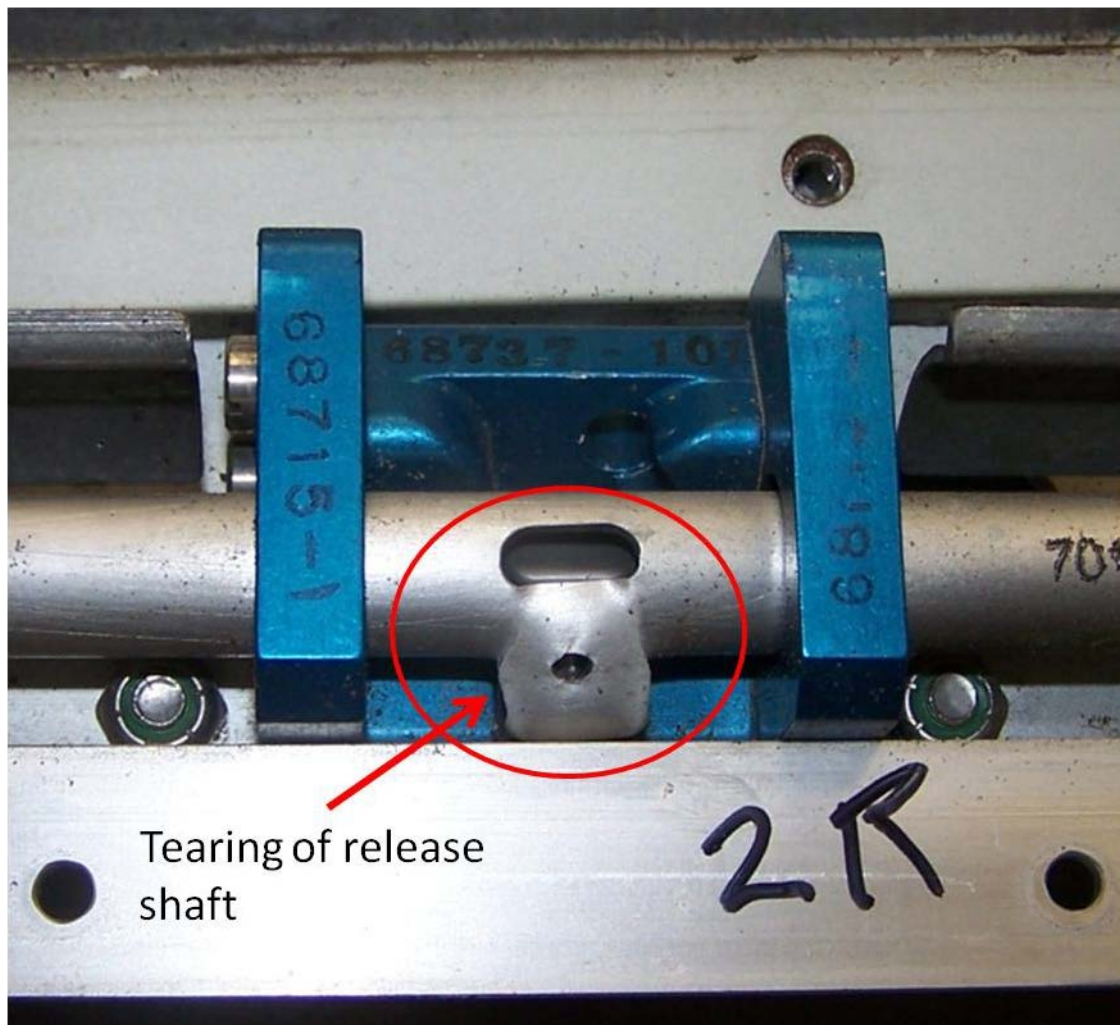


**Figure 8. Door 1 Right Hand**



## 5.0 In-Cabin Slide/Raft Inflations

On July 30-31, 2013, a teardown study of much of the evacuation system equipment occurred at Air Cruisers in Wall, NJ with the on-site support of Asiana, Boeing, FAA and NTSB. A primary discovery was that the right side systems suffered from damage to the packboard release shaft. The extreme loads seen during the crash were transmitted from the bulk of the slide/raft pack, concentrating on the upper and lower lacing cover attachments to the packboard. The lower lacing cover is attached to the release mechanism, therefore much of the crash load was exerted on the release shaft. This shaft could not withstand the excessive forces and failed, allowing the shaft to rotate, thereby releasing the cable ball ends from their engagement with the shaft roll pins. See Figure 9 for typical release shaft damage seen on the evacuation systems on the right hand side of the aircraft.



**Figure 9. Typical Release Shaft Damage – Right Side of Aircraft**

## 6.0 Post-Teardown Testing

### 6.1 Tensile Testing

On November 7, 2013 at Air Cruisers in Wall, NJ, a tensile test machine was used to destructively pull on (6) packboard release mechanisms in an effort to reproduce the damage seen on the right sided evacuation systems and to understand the level of force required to release the packed slide/raft. See Figure 10 for test setup. This testing successfully reproduced the damage. The pull force required to cause the damage similar to that seen on the Asiana Flight 214 right hand systems ranged from 1465 to 1781 pounds. The lowest value was from a release assembly replicating the pin shield fastener condition found on Door 1 Right Hand. Those with properly fastened pin shields had failure values ranging from 1631 to 1781 pounds. When considering the weight of the pack contained within the lacing cover, this force equates to values within the range of 8g's to 16g's. These values only serve as guidance to assist in planning of the acceleration testing as described in Paragraph 6.2 since the tensile tests do not represent the dynamic nature of a crash load.

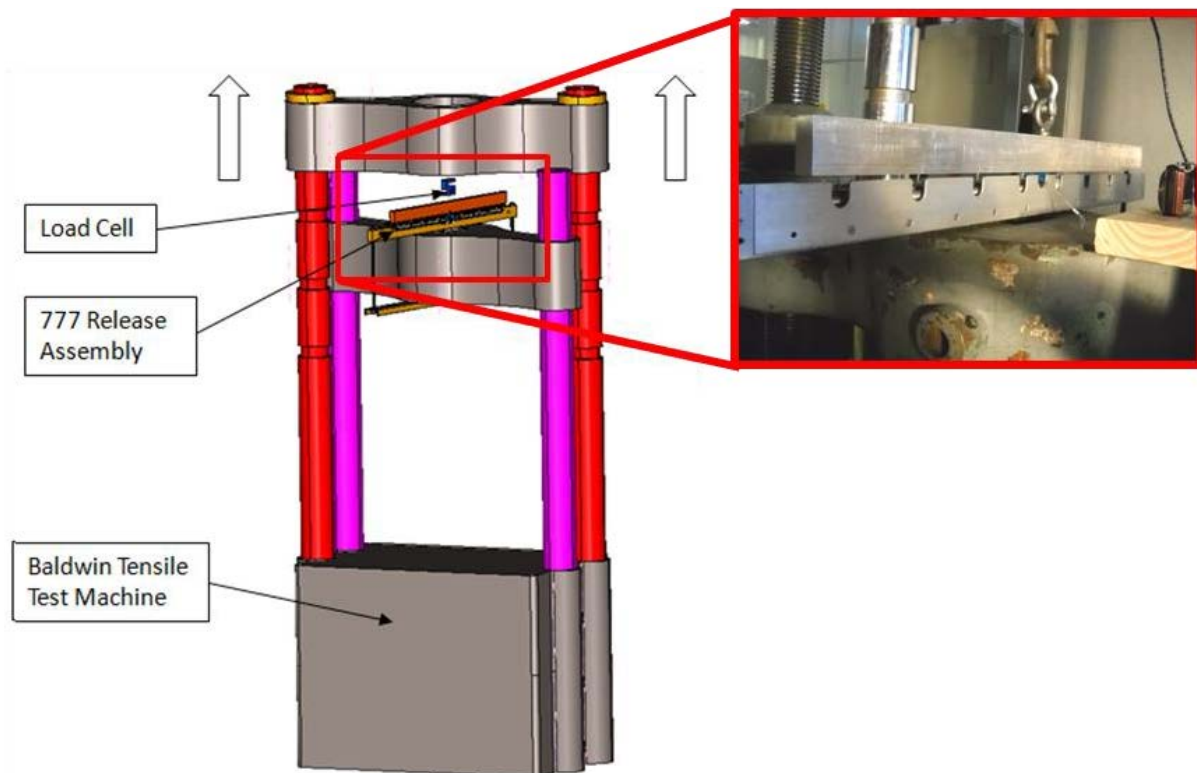


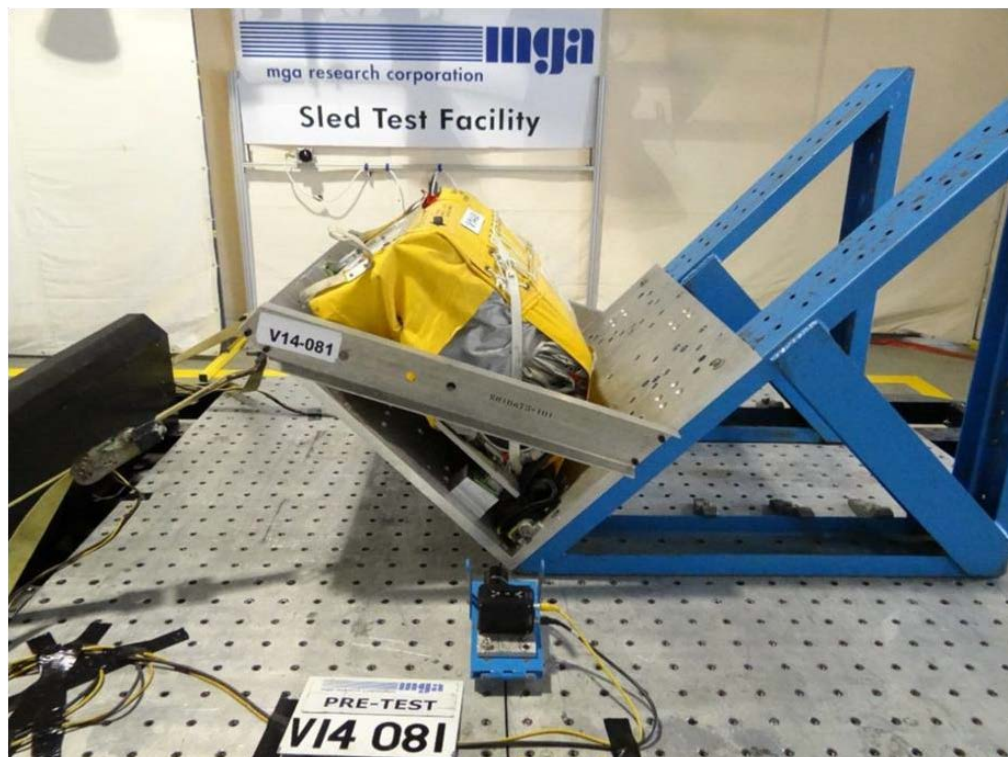
Figure 10. Tensile Test Setup



## 6.2 Acceleration (Sled) Testing

On January 21-22, 2014, acceleration testing was conducted at MGA Research in Manassas, VA under contract with the NTSB. The purpose of this test was learn the amount of dynamic force required to cause the slide/raft to release from the packboard. An additional goal was to reproduce the same type of damage seen during teardown of the slide/rafts on the right side of the Asiana Flight 214 aircraft. Testing in the inboard only direction resulted in pack release above 14g's, however the failure mode was not consistent with that seen on the Asiana units. Instead, the inboard only direction resulted in the balls separating from the release cables with no damage seen to the release shaft. Additional testing was conducted in both the down condition as well as the 45° orientation (combining the down and inboard directions). See Figure 11. Tests in these directions reproduced the damage seen on the Asiana Flight 214 units and occurred at values in excess of 12.4g's. This value exceeds the 3g inboard and 6g downward loads as specified in FAR 25.561 (b) as well as the 6.8g downward load as qualified on these 777 systems per Boeing requirements.

The acceleration testing only determines the minimum load required to cause the slide/raft to release from the packboard. It can be inferred that the Asiana Flight 214 aircraft saw at least this level of impact force (12.4 g's) as part of the crash sequence.



**Figure 11. Acceleration Test Setup (45° Shown)**



## **7.0 Additional Observations/Actions**

### **7.1 Pin Shield Fasteners**

As discussed in Paragraph 4.7, one of the slide/raft systems exhibited missing and loose pin shield fasteners. The fastening consisted of #4-40 screws threaded into tapped aluminum threads with the use of a lockwasher. The subject unit with the missing and loose fasteners had these parts replaced by Asiana mechanics as part of a service bulletin for the release housing. A review of drawings and component maintenance manuals showed that a specific torque value was not specified for installation of those fasteners. Air Cruisers took the action to add a torque value to the assembly drawings as well as the CMM's. In addition, a product improvement was implemented for new production systems to use liquid threadlocker in place of lockwashers.

### **7.2 Power Unit Activation Lanyard**

It was discovered during teardown of the Door 3 left hand slide/raft that an improper power unit lanyard was rigged to the slide. In addition, a "dummy" lanyard was installed separately into the power unit. This would have resulted in failure of the lighting system to activate. A "dummy" lanyard, also referred to as a shipping lanyard, is provided with every new power unit. Its purpose is to prevent the power unit from self-discharge during shipping and storage, prior to being installed on a slide/raft. This lanyard has no part number identified. The CMM for the slide/raft systems require a part number marked lanyard assembly with a specific length. The "dummy" lanyard looks similar to the part-marked lanyard assembly. Air Cruisers took an action to update the CMM's to specify that new power units are shipped with a shipping lanyard and this lanyard needs to be removed and discarded upon rigging to the slide/raft.